mentation of a household-sticker plan. The VMT reductions of such a plan are fairly uniform for households of all incomes. This uniformity arises partly from the fact that, although lower-income households are more sensitive to changes in levels of automobile availability, such households are likely to own fewer vehicles than higher-income households.

As Table 1 indicates, a household-sticker plan has the potential for inducing substantial reductions in the shadow price of fuel. Furthermore, it is indicated that the distribution of stickers that control weekend and weekday automobile use can have a significant impact on plan effectiveness. The net effects of the plan are generally to shift VMT from work trips to social-recreational trips and to shift work trips away from the drive-alone mode.

SUMMARY AND CONCLUSIONS

This research has developed a modeling system that considers the complex interactions between various travel demand components and proposed energy contingency plan options. Because the modeling system uses a number of Monte Carlo simulation techniques that require minimal amounts of data, it can readily be adapted to the consideration of alternative geographic areas and to test a wide variety of possible policy options. In the current study, the model was applied on the national level in an effort to forecast the likely travel-related impacts induced by various energy contingency plans.

The results of the model applications indicate that a relatively wide range of impacts relating to fuel consumption, income effects, and other factors can be achieved with alternative contingency plans. Of the limited number of plans considered in this study, the household-sticker and four-day-work-week measures produce the largest reductions in the demand for gasoline. In terms of the income impacts of these two plans, the sticker measure provides for an equitable distribution among income groups whereas the shortened work week disproportionately affects higher-income brackets. However, it must be recognized that the evaluation of contingency measures should not be based entirely on the impacts addressed in this study, since the implementability, costs, and enforceability of a measure are also critical factors in the selection of an appropriate plan.

ACKNOWLEDGMENT

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Direct Energy Consumption for Personal Travel in the Chicago Metropolitan Area

D.E. BOYCE, B.N. JANSON, AND R.W. EASH

A set of calculations of direct energy consumption for the Chicago region is prepared. The methodology for developing the energy accounts is illustrated by using two examples for a transit and an automobile trip. Direct operating energy statistics for personal travel are shown in both tabular and mapped forms. Both absolute energy consumption and rates of energy consumption by areal unit are listed. Tables showing how energy consumption varies with trip origin and destination are discussed, and maps that show the energy consumption contours for travel to the Chicago central business district are presented.

This paper presents estimates of direct energy consumption for peak-period weekday person travel in the Chicago region. The methodology is a logical and marginal extension of the current "state-of-the-art" urban transportation demand models (1). All software is compatible with the widely used Urban Mass Transportation Administration/Federal Highway Administration (UMTA/FHWA) Urban Transportation Planning System (UTPS) (2) and the FHWA PLANPAC battery (3) of computer programs for urban transportation planning. Therefore, the methodology for computing energy consumption, in concert with the standard programs for transportation planning, is applicable to a wide range of planning problems, including evaluation of short-range, low-capital transportation improvement options as well as the more standard long-range, capital-intensive system alternatives.

The accounts or estimates presented in this paper are for direct energy consumption, which primarily consists of energy for vehicle operation. For travel by private mode, specifically not included in the calculations is energy consumed in construction and maintenance of automobiles, garaging of automobiles, and highway construction, maintenance, and operation. In the case of public transportation, energy used in construction and maintenance of public transportation terminals and traveled ways is also excluded from these estimates; energy used in operation of transit stations and other vehicle-related facilities is included.

In general, energy consumption is reported in British thermal units (Btu). The factors used in the calculations to convert from liquid measure to energy units are 125 000 Btu/gal of gasoline and 138 700 Btu/gal of diesel fuel. The same conversion factor is used for all diesel-powered modes regardless of whether they are highway or rail. All estimates given were developed from simulations of morning-peak-period weekday personal travel.

EXAMPLES OF ENERGY CALCULATIONS

The procedures for calculating private and public energy consumption can be applied to an individual trip movement that corresponds to a single cell in a trip table. Individual trip calculations can be carried out easily by hand; two examples are worked in this section to illustrate the methodological approach. All calculations are exactly as they would be completed in the computer programs prepared for the analyses.

The first example considered is a public-mode trip between zone 134, on the south side of Chicago, and the Chicago central business district (CBD). Zone 134 is bounded by 103rd Street on the north, 111th Street on the south, Halsted Street on the west, and Michigan Avenue on the east. The table below gives the minimum-time path by bus and rail transit between zone 134 (south-side Chicago) and zone 64 (the Chicago CBD):

A Node	B Node	Travel Mode	Transit Line Used
134	3476	Walk	
3476	3605	Bus	196, 223
3605	2183	Transfer	
2183	2092	Rail rapid transit	26
2092	4523	Transfer	
4523	64	Walk	

The table is read as follows. Starting at the centroid of zone 134, the patron walks to a bus stop at 103rd and Michigan Avenue (node 3476), boards a northbound Michigan Avenue bus, and rides to the 95th Street Dan Ryan rail transit terminal stop (node 3605). The rider walks from the bus stop to the train platform (node 2183) and boards a northbound Dan Ryan train. After riding to the Loop, the patron alights from the train at the station at State and Lake Streets (node 2092), walks to the intersection of Dearborn and Lake Streets (node 4523), and goes on to the destination zone 64 centroid. It is important to understand that this path is not the minimum-energy-consumption path but the minimum-time (a weighted combination of waiting, walking, and riding time) path between zones.

The portions of this trip that are of interest from an energy-consumption standpoint are the bus and rail transit "legs". Only one bus link is used by the rider (node 3476 to node 3605). The two bus lines that operate over this link carry a total of 2665 riders on 47 trips. The link is 1.3 miles long. Energy consumed per person trip on the link is calculated as follows:

$$\text{(Btu per bus vehicle mile)} \times [(\text{number of bus trips} \times \text{link length}) \div \text{patronage}] = \text{Btu per person trip} \quad (1)$$

Substituting the actual estimates determined by Boyce and others (1) for bus fuel consumption and ridership into this equation gives 42 000 x [(47 x 1.3)/2665] = 960.

The rail transit calculation is similar except that more than one link is involved. Table 1 lists 12 rail transit links between nodes 2183 and 2092. The computations in Table 1 provide the vehicle miles that are charged against each rider on the listed links. During the morning peak period, 42.4 northbound trips of eight-car trains occur; thus, 342.4 vehicle miles are generated by each mile of track. Dividing vehicle miles on each link by the patronage on the link produces the vehicle miles assignable to each rider.

For the trip in question, approximately 0.21 vehicle mile of rail transit output is consumed by each person trip. At 57 000 Btu/rail transit vehicle mile (4), each person trip consumes 11 980 Btu. Adding this energy to that already used for travel to the station by bus produces a total of 12 940 Btu/person trip.

If access to the 95th Street rail transit station is by private automobile, then the gasoline consumed in driving to the station must be substituted for the energy consumed in gaining access by bus. The average distance to the station (a weighted average determined by location of residences within the zone) from the origin zone is 2.2 miles. If one uses the regional average automobile gasoline consumption of 12.7 miles/gal, each mile driven consumes about 9800 Btu. Multiplying this per-mile energy consumption times distance to the rail transit station shows that 21 560 Btu/trip is needed to gain access to rail by automobile. If the return automobile trip is also charged against the automobile access portion of the entire movement, then 43 120 Btu is required for station access by automobile. These results are summarized below:

	Energy Use (Btu)		
Trip Type	Access	Line-Haul	Total
Public mode only	960	11 980	12 940
Automobile driver access to rail	21 560	11 980	33 540
Automobile passenger access to rail	43 120	11 980	55 100

For private automobile trips, as many as five paths are identified between each pair of zones. In this example, energy consumption along only one of the five paths is investigated. One of the automobile minimum-time paths between zone 134 and zone 64

Table 1. Energy calculations for rail transit.

A Node	B Node	Link Length (miles)	Vehicle Miles	No. of Riders	Vehicle Miles per Rider
2183	2182	1.0	342.4	8 026	0.042 66
2182	2181	1.0	342.4	12 085	0.028 33
2181	2180	1.2	410.9	17 344	0.023 69
2180	2179	0.8	273.9	24 931	0.010 99
2179	2178	1.0	342.4	25 433	0.013 46
2178	2177	1.0	342.4	25 573	0.013 39
2177	2176	1.5	513.6	25 574	0.020 08
2176	2175	1.5	513.6	27 147	0.018 92
2175	2099	2.1	719.0	26 887	0.026 74
2099	2100	0.2	68.5	19 852	0.003 45
2100	2101	0.2	68.5	16 014	0.004 28
2101	2092	0.2	68.5	16 384	0.004 18
Total		11.7	4006.1		0.210 17

Table 2. Warm-engine gasoline use for example path.

Street	A Node	B Node	Length (miles)	Time (min)	Gasoline (gal)
Halsted Street	134	2721	0.50	1.30	0.0366
	2721	2723	0.52	1.20	0.0360
	2723	6603	0.11	0.28	0.0080
Ramp	6603	6602	0.12	0.25	0.0079
Dan Ryan Expressway	6602	3668	0.71	0.99	0.0393
	3668	3662	0.45	0.78	0.0239
	3662	2125	0.47	0.74	0.0256
	2125	10467	0.68	1.16	0.0362
	10467	10463	1.00	1.45	0.0553
	10463	10715	0.49	0.76	0.0268
	10715	10457	0.20	0.38	0.0106
	10457	6607	0.52	0.68	0.0293
	6607	10451	0.29	0.68	0.0153
	10451	10448	0.26	0.69	0.0138
	10448	10447	0.82	1.91	0.0434
	10447	10419	0.50	0.71	0.0277
	10419	10397	1.00	1.48	0.0551
	10397	10389	0.87	1.58	0.0461
	10389	4116	1.75	2.71	0.0957
	4116	10365	0.05	0.99	0.0034
	10365	5697	0.53	0.85	0.0287
	5697	10704	0.41	1.13	0.0218
Cermak Road	10704	9797	0.04	0.55	0.0037
Clark Street	9797	9796	0.14	0.95	0.0129
	9796	3783	0.19	3.19	0.0175
	3783	72	0.67	11.18	0.0617
	72	12132	0.33	5.49	0.0304
Polk Street	12132	3718	0.08	1.65	0.0074
Dearborn Street	3718	3717	0.14	0.69	0.0129
	3717	4042	0.08	0.39	0.0074
	4042	4041	0.06	0.45	0.0055
	4041	4036	0.09	1.37	0.0083
	4036	4037	0.09	1.04	0.0083
	4037	4024	0.09	0.44	0.0083
	4024	4025	0.09	0.44	0.0083
	4025	3967	0.08	0.37	0.0074
	3967	3968	0.10	0.49	0.0092
Randolph Street	3968	5691	0.07	0.18	0.0051
	5691	64	0.08	0.23	0.0062
Total			14.67	51.80	0.9070

Table 3. Peak-period regional direct energy consumption.

Travel Category	Petroleum-Based Fuel (gal)	Petroleum (billions of Btu)	Electric (billions of Btu)
Public travel			
Bus			
Nonaccess	11 800	1.63	
Access	1 600	0.22	
All overhead	1 500	0.21	
Rail rapid transit			2.46
Rail rapid transit overhead			0.04
Commuter rail diesel	14 400	2.00	
Commuter rail diesel overhead	100	0.02	
Commuter rail electric			0.97
Automobile access	14 700	1.84	
Subtotal	44 100	5.92	3.47
Private travel	1 344 500	168.07	
Total	1 388 600	173.99	3.47

begins at 107th and Halsted Streets and continues north on Halsted to the Dan Ryan Expressway. It then proceeds north on the expressway to the Franklin Street extension of the expressway. The path then jogs east on Cermak Road to Clark Street, turns north on Clark to Polk Street, and then turns east on Polk to Dearborn Street. The Chicago Loop is entered by way of Dearborn, and the path finally turns west on Randolph Street to LaSalle Street, where the zone 64 centroid is located.

The links in this path are given in Table 2 along with link travel times and distances. Time and distance plus link type are used with gasoline consumption coefficients developed from several sources (5-8) to obtain the final column of warm-engine gasoline consumption per link for an average automobile. Total warm-engine fuel consumption for the complete path is 0.907 gal.

Excess cold-engine gasoline consumption must be added to the warm-engine consumption. Excess cold-engine consumption occurs only over the first 8.5 miles of a trip; since the path in question is longer than 8.5 miles, a lump sum of 0.125 gal of excess cold-engine consumption is added. Thus, a total of 1.032 gal of gasoline, or 128 750 Btu, is consumed during the trip.

REGIONAL ENERGY CONSUMPTION

Table 3 summarizes the estimates of regional direct energy consumption. These findings are broken down into the two primary modes, public and private. Public transportation is further subdivided into submodes in this table. Automobile access trips to public transportation are included under public travel. Total consumption in the region for the morning peak period is approximately 175 billion Btu. Only about 2 percent of this total represents electrical energy consumption by commuter rail and rail rapid transit. Petroleum-based fuels are the overwhelming source of transportation energy in the region because automobile travel accounts for 95 percent of the total energy listed in the table.

The remaining 5 percent of energy for morning-peak-period person travel is for public transportation. Within public transportation, more than half of the operating energy is taken for commuter rail trips (all commuter rail energy plus almost all automobile and bus access energy). The "overhead" modal energy given in Table 3 is for nonproductive vehicle miles. Here, the term nonproductive refers to vehicles running on links that do not have trips assigned to them; thus, they are nonproductive scheduled service rather than movements to, from, and within garages and storage yards. Vehicle miles traveled for maintenance and storage are not included, nor is the extra fuel consumed during engine idling in both public and private modes.

Figures 1 and 2 show direct energy consumption for private and public transportation by district of trip origin. These plots reflect (a) the number of trips in the district, (b) the spatial distribution of the destinations of these trips, and (c) the operating conditions these trips face. For example, the heavy private energy consumption in the mid-northwest sectors results from the number of trips in the district, the vehicle miles generated by these trips, and the traffic congestion encountered. One cannot infer any relative energy efficiencies from these two maps because they show gross

Figure 1. Peak-period energy consumption by origin district: private transportation.

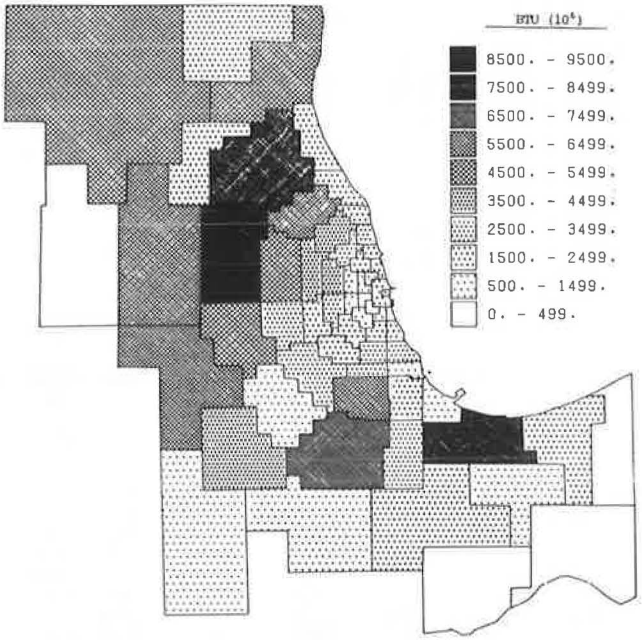
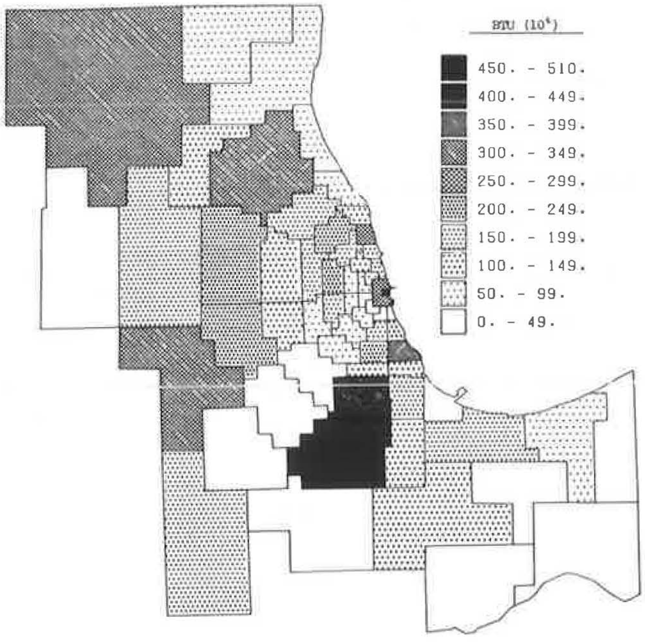


Figure 2. Peak-period energy consumption by origin district: public transportation.



energy consumption instead of rates.

In comparing the two maps, it should be noted that the entire scale of the public-transportation map nearly fits within the lowest rank of the private-transportation map scale. The maximum district energy consumption for public transportation is about 500 million Btu, whereas the largest use in any private-transportation district is around 9 billion Btu. For private transportation, the scale corresponds to a range of gasoline consumption between 0 and 76 000 gal, where each rank interval equals 8000 gal.

There is no clear pattern in the energy consumption for the two primary modes revealed in these two figures. An analyst might anticipate a well-defined concentric pattern of consumption for public transportation due to the proportion of CBD-directed movements in trips by public transportation. But any trend is hard to discern because there are few public-mode trips in the outlying zones. Automobile trips are less focused on any one destination, and private-transportation energy consumption does not exhibit a regular pattern.

Rates of Energy Consumption for the Primary Modes

Rates of energy consumption are far more meaningful than absolute quantities for intermodal comparisons. The following table gives operating energy consumption for the two primary modes in Btu per person trip, Btu per person mile of travel, and Btu per person air mile of travel:

Statistic	Private Travel	Public Travel
Peak-period Btu (billions)	168.07	9.39
Person trips served	2 965 368	511 751
Btu per person trip	56 678	18 349
Person miles traveled	21 106 312	4 818 405
Btu per person mile	7963	1949
Person air miles traveled	17 647 717	4 435 593
Btu per person air mile	9524	2117

The methods for calculating person-trip rates and distance rates differ slightly. All person trips are included in the person-trip rate, but only person trips assigned to the network (interzonal trips) are included in the travel-distance calculations (person trips served include interzonal trips whereas person miles and air miles traveled do not include intrazonal trips).

The per-trip energy consumption for private transportation is about three times the per-trip consumption for public transportation. But this comparison ignores the fact that different trips are served by the two modes. Public transportation is even more efficient when compared on a person-mile basis. If one measures efficiency by using person miles, the ratio is almost four to one in favor of public transportation. This latter comparison, however, ignores the different average trip circuity for the two primary modes. Person miles of travel can also be generated by inefficient indirect routings.

The preferred statistic is the energy consumed per person air mile of travel; that is, energy consumption per mile of point-to-point distance. When consumption is measured as a person-air-mile rate, the ratio between public- and private-mode consumption increases to about 4.5 to 1 in favor of public transportation. Somewhat surprisingly, public-transportation trips in Chicago are, on the average, less circuitous than private-mode trips.

Figures 3 and 4 show two maps that plot the public- and private-mode morning-peak-period average energy consumption per person air mile by district of trip origin. These two maps are clearly different: The public-transportation map is almost a negative of the private-transportation map. Districts that have high rates of consumption on the public-mode map have low rates on the private-mode map and vice versa. Energy consumption rates for private transportation are highest in the urban developed districts, whereas rates for public transportation are highest in the far suburban districts.

Like the scales in Figures 1 and 2, the scales in Figures 3 and 4 are quite different. The highest district average rate for public transportation is less than the lowest district average rate for private transportation. The maximum district average rate of energy consumption per person air mile is 11 100 Btu for private transportation. About 6500 Btu/person air mile is the maximum consumption rate for public transportation.

The rates shown in these two maps and in the table on page 19 are valid only for the existing pattern of regional travel and the existing split of these trips between private and public modes. Any shift of mode choice or redistribution of trip destinations will affect these rates of energy consumption. Strictly speaking, modal energy rates should not be directly compared except when the productive output (the number of persons moved between each origin-destination pair) is the same for the two modes.

The public-transportation energy consumption rates reflect that public-mode trips are heavily focused on the CBD and can be efficiently carried by radial high-capacity line-haul services. Trip desire lines for public transportation are limited compared with the travel pattern of private mode trips. The less well-defined desire lines of private transportation are much less suitable for service by high-capacity public modes.

The difference between existing public- and private-mode travel and the relation between modal travel patterns and energy consumption are further clarified by the data in Table 4, which gives rates of energy consumption and average trip lengths by ring of trip origin. Trip lengths for CBD-originating trips by private mode are much shorter than those for CBD-originating trips by public transportation. Away from the downtown, trip lengths by private mode are fairly constant across the region whereas trip lengths by public mode regularly increase with distance from the CBD. Again, this points out the different character of the two trip populations served by the two primary modes.

These average trip lengths explain why private-mode energy consumption per trip is nearly constant across the region compared with public-mode consumption per trip. Average energy consumption per person trip is roughly the same for private-mode origins in rings 2-8. Slightly longer trip lengths for trips from the outer rings are balanced by more efficient automobile operation due to less traffic congestion in these rings. The energy required for public-mode trips increases with distance from the CBD because of longer trip lengths and also because of less efficient vehicle use at the ends of transit lines where vehicle occupancy levels are lower.

Table 5 repeats the information in Table 4 but tabulates the data by trip destination. Private-mode trip lengths and energy consumption are practically the same as those in Table 4 except for the innermost rings. In the outlying rings, the pri-

Figure 3. Peak-period energy consumption per person air mile by origin district: private transportation.

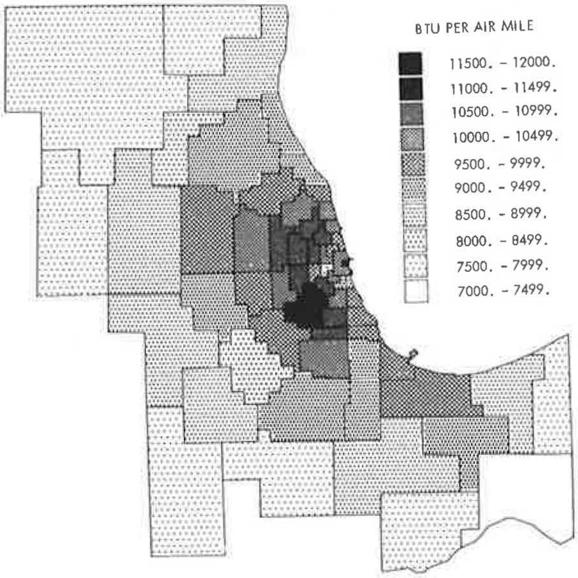


Figure 4. Peak-period energy consumption per person air mile by origin district: public transportation.

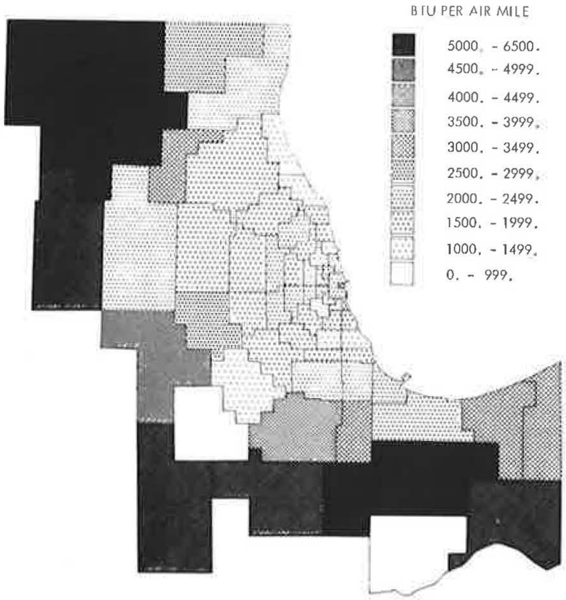


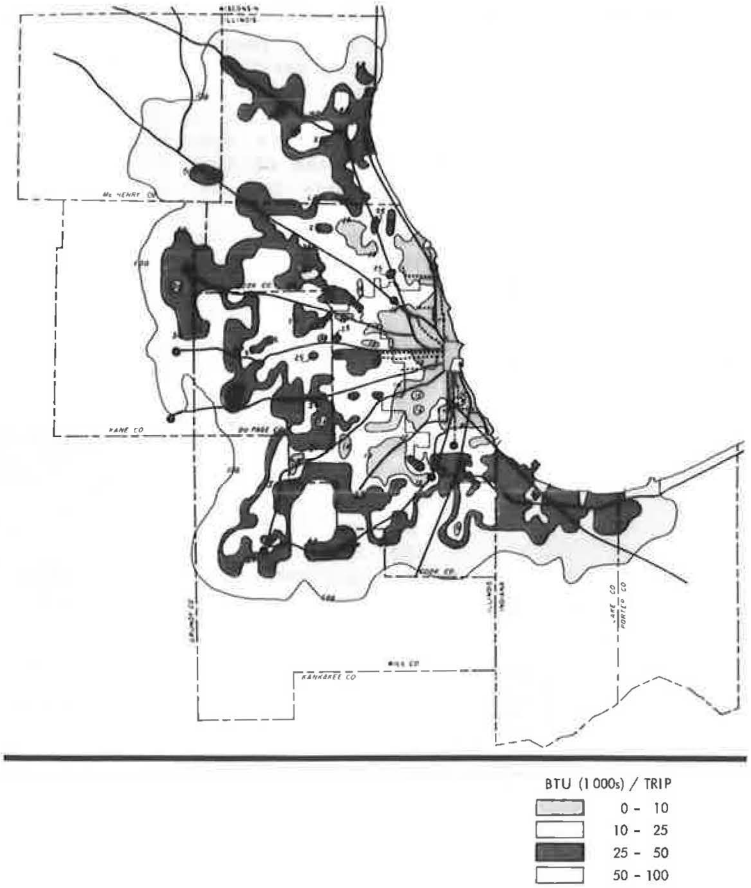
Table 4. Morning-peak-period energy consumption by ring of origin.

	Private Mode			Public Mode		
Ring of Origin	Avg Trip Length (miles)	Btu per Trip	Btu per Person Air Mile	Avg Trip Length (miles)	Btu per Trip	Btu per Person Air Mile
0	1.8	18 800	10 700	8.3	27 800	3300
1	3.5	35 200	10 200	5.7	12 700	2200
2	6.0	57 800	9 600	4.4	7 300	1700
3	5.6	57 800	10 400	5.8	8 400	1500
4	5.6	59 200	10 700	7.1	11 000	1600
5	5.2	54 800	10 400	8.7	16 600	1900
6	5.4	53 700	9 900	12.7	23 500	1900
7	6.2	58 400	9 400	18.7	46 100	2500
8	6.6	58 100	8 700	23.8	72 600	3100

Table 5. Morning-peak-period energy consumption by ring of destination.

	Private Mode			Public Mode		
Ring of Destination	Avg Trip Length (miles)	Btu per Trip	Btu per Person Air Mile	Avg Trip Length (miles)	Btu per Trip	Btu per Person Air Mile
0	7.8	76 600	9 800	10.8	19 600	1800
1	9.6	91 000	9 500	9.7	18 700	1900
2	6.6	66 800	10 100	5.7	10 500	1900
3	5.7	61 000	10 700	4.7	10 900	2300
4	5.0	53 500	10 600	5.1	15 000	2900
5	5.5	56 300	10 300	6.4	20 900	3200
6	6.1	59 300	9 800	9.6	24 400	2500
7	5.8	52 300	9 100	15.2	28 900	1900
8	5.9	51 400	8 600	18.1	34 800	1900

Figure 5. Energy consumption to the Chicago CBD: public transportation.



vate-mode trip lengths calculated by trip origin and trip destination are fairly close, which indicates little directional imbalance in these trips. The two most central Chicago rings do have longer destination trip lengths than origin trip lengths because employment in these rings is drawn from residences far outside the central area.

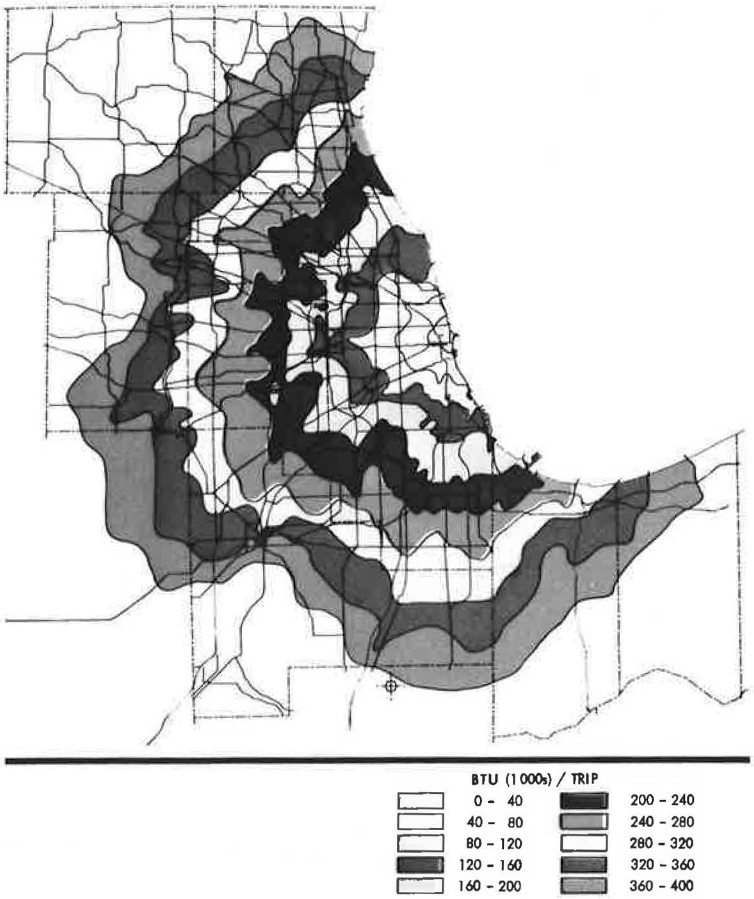
Public-transportation trip lengths exhibit the same pattern regardless of whether they are tabulated by origin or destination. The longest public-mode trips are those that begin or end in the innermost and outermost rings, and the shortest trips belong to the middle rings. Energy consumed per trip follows this same pattern. It should be noted, however, that the relation between energy and trip length does vary.

Energy consumption per person air mile for public transportation is more difficult to explain. Energy consumption efficiency for public modes for trips destined for rings farther away from the Chicago CBD decreases until ring 6; then, public-mode efficiency improves. Apparently, the capacity offered by public transportation (chiefly commuter rail) more closely matches patronage for trips to outlying destinations than it does for trips to rings closer to the downtown. The reverse-direction trips to these inner rings are carried generally by rail rapid transit and bus lines that offer nearly the same capacity in the peak and reverse-peak directions.

Energy Consumption for Travel to the CBD

The final two maps in this section show the energy required by the two primary modes to reach the Chicago CBD. Contours for public-transportation energy consumption are shown in Figure 5, and a similar map for private transportation is shown in Figure 6.

Figure 6. Energy consumption to the Chicago CBD: private transportation.



These maps show how accessible, in terms of energy consumption, the Chicago CBD is from all points in the region.

The two maps are very different, both in the appearance of the energy contours and in the contour values. The private-mode contours are more regular in shape and cover a wider range of values than the public-mode contours. The contours of the two maps are not set at the same values.

In the public-mode map, the contours are not uniformly spaced because the rate of public-mode energy consumption per unit of distance increases substantially as one moves away from the area covered by the regular grid of Chicago Transit Authority lines. Almost all of the city of Chicago is contained within the initial 10 000 Btu contour. But in the outer suburbs, contours 10 000 Btu apart would only be separated by approximately a mile when the automobile is used as an access mode.

Contours in the public transportation map tend to extend out along the commuter rail lines so that almost every point in the region that has direct public service lies within the 50 000-Btu contour. As soon as automobile access is required to reach public modes, the energy consumed quickly rises. There are also a number of "dimples" that lie between contours. These arise because some zones within an area of service still do not have direct public-mode service or because service is provided only by a lightly patronized line. Automobile access to rail transit energy consumption is computed by assuming single-occupancy one-way trips.

Contours on the private-mode map reach much higher values than those on the public-mode map. The 50 000-Btu contour for private transportation covers only a portion of the city of Chicago. Maximum private-mode contours are in excess of 300 000 Btu. Automobile occupancy levels are not incorporated in this map. The contours show average automobile energy consumption to reach the Chicago CBD and not person-trip energy consumption.

CONCLUSIONS

Many earlier studies have published data on the energy-intensiveness of different modes as measured by energy consumed per passenger mile, vehicle mile, ton mile, seat mile, or similar output measure. It is hoped that the reader understands that intermodal comparisons made on the basis of these figures are often misleading. Such comparisons ignore that passenger-mile and ton-mile outputs can be generated by grossly inefficient transportation services. For example, heavily laden vehicles that travel indirect routes can have low energy-intensiveness per ton mile and still be energy inefficient.

Comparisons of modal energy-intensiveness also ignore that low-energy-intensive line-haul modes may depend on high-energy-intensive modes for access and distribution from line-haul terminals. One has only to note that public-mode energy consumption should include energy consumption for automobile station access. For similar reasons, this paper does not compare rail transit with bus. A large portion of rail transit trips in the Chicago region cannot be completed without also using a bus for a portion of the trip.

The results of these analyses for the two primary modes can be summarized as follows. The direct energy consumption estimate of approximately 2000 Btu/person air mile for public transportation in the peak period can essentially be regarded as the maximum efficiency attainable by public transportation. The circumstances are ideal for efficient mode use, the market served has well-defined travel desire lines, and vehicles are operated near capacity. Private modes, in contrast, are operated with much lower vehicle occupancies and serve a relatively dispersed travel market.

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Short-Term Forecasting of Gasoline Demand

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Techniques used recently by the U.S. Department of Energy to forecast short-term demand for motor-vehicle gasoline are reviewed. Techniques used during and before 1979 are discussed briefly, and the rationale for the development of new methods during 1980 is also presented. Because the forecasting effort is an ongoing one, the procedures evolve over time. Only the techniques developed during 1980 are treated in detail, but a brief discussion and summary of the older methods are provided for comparison purposes. The current forecasting technique relies on predetermined parameter values rather than econometrically estimated values. This is the result of an evaluation of the econometric estimates. The new procedures have resulted in improved forecast accuracy and have anticipated the downturn in motor-vehicle gasoline demand that occurred in 1980. The current model computes annual demand for 1980 within 1.0 percent of actual demand, and the average error for the monthly demand estimates during 1980 is less than 2.5 percent of actual demand. The current techniques can be used to project the effects of various policy options, such as improved mileage requirements or gasoline tax levies.

The Short-Term Analysis Division (STAD) in the Energy Information Administration (EIA) of the U.S. Department of Energy is responsible for projecting demands, supplies, and prices of all energy products on a monthly basis, nationally. To do this, STAD uses the Short-Term Integrated Forecasting System (STIFS) (1), which is an iterative balancing procedure, and several "satellite" demand models, one of which is the Motor Gasoline Demand Model. This paper describes the activities that STAD has undertaken in its search for a credible procedure for forecasting the demand for gasoline for use in STIFS.

There are several reasons for undertaking the development of a new short-term forecasting model for motor gasoline demand for STIFS:

1. Several past studies have examined the demand for motor-vehicle gasoline on the Petroleum Administration for Defense Districts (PADD) level. STIFS requires a national basis. STAD felt that one national model could replace the five separate PADD models previously developed.

2. Gasoline prices were relatively constant over the estimation period of the earlier models. However, changes in gasoline price have recently become volatile. This volatility has led to the notion that perhaps a shift in demand is taking place.

3. Several regional price elasticities in the PADD-level model used for the EIA 1978 Annual Report (2) were estimated to be insignificantly different from zero. The rapid increases in price and the effect on demand belie this finding.

4. The linear structure of the gasoline model used in the EIA February 1980 Short-Term Energy Outlook (3) led to large elasticities when faced with the rapid price increases in 1979 and 1980 following the Iranian revolution. The February report used both an econometric methodology and, in the appendix, a simple parametric procedure.

These considerations led to the development of the current gasoline demand model, which underlies the demand projections for the EIA 1979 Annual Report to Congress (4) and subsequent Short-Term Energy Outlooks following the February 1980 report. The parameters of the current model are specified rather than econometrically estimated. This is an interim methodology until a behavioral model that uses household data currently being collected by EIA can be estimated.

EIA's early gasoline models were typically linear regression models. Demand for gasoline was the dependent variable, and real price, real disposable